SMAP Sea Surface Salinity Retrieval Algorithm

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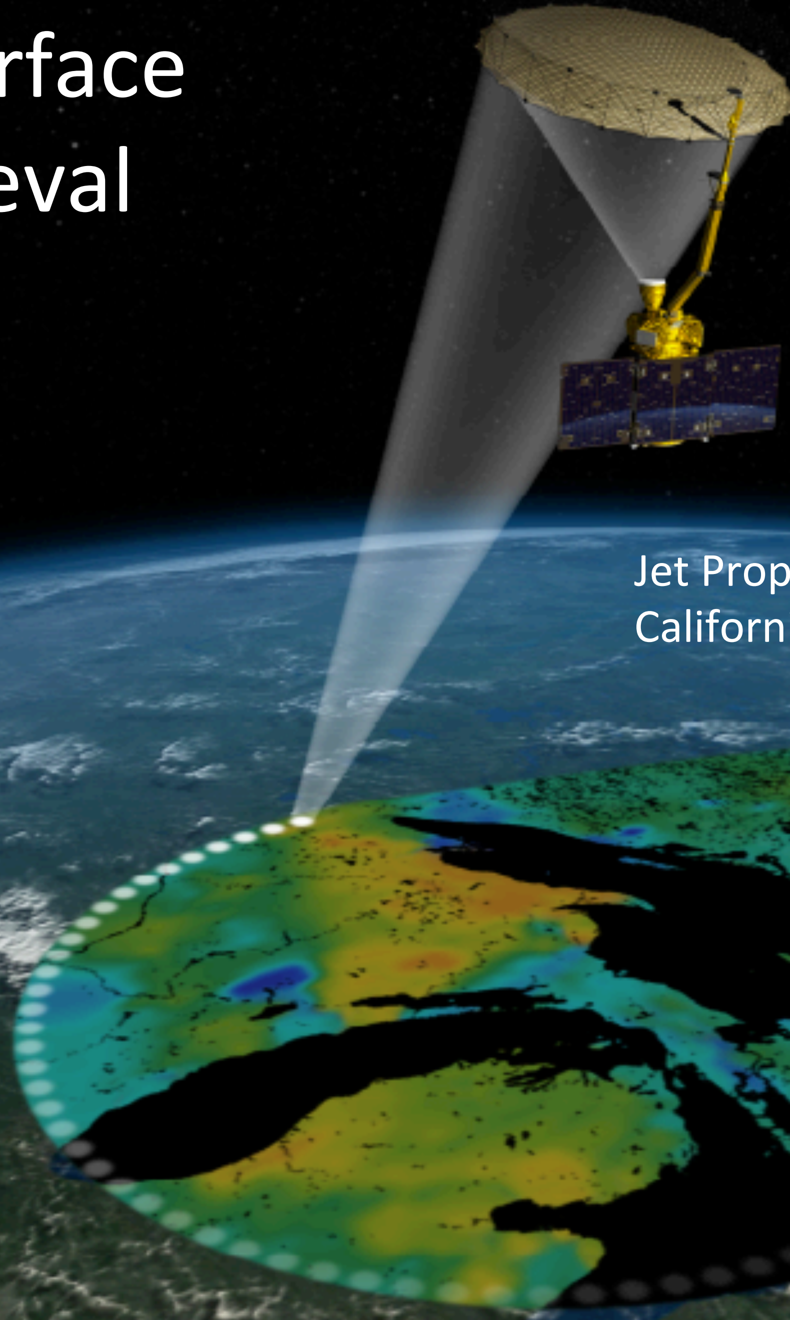

AGU Ocean Sciences
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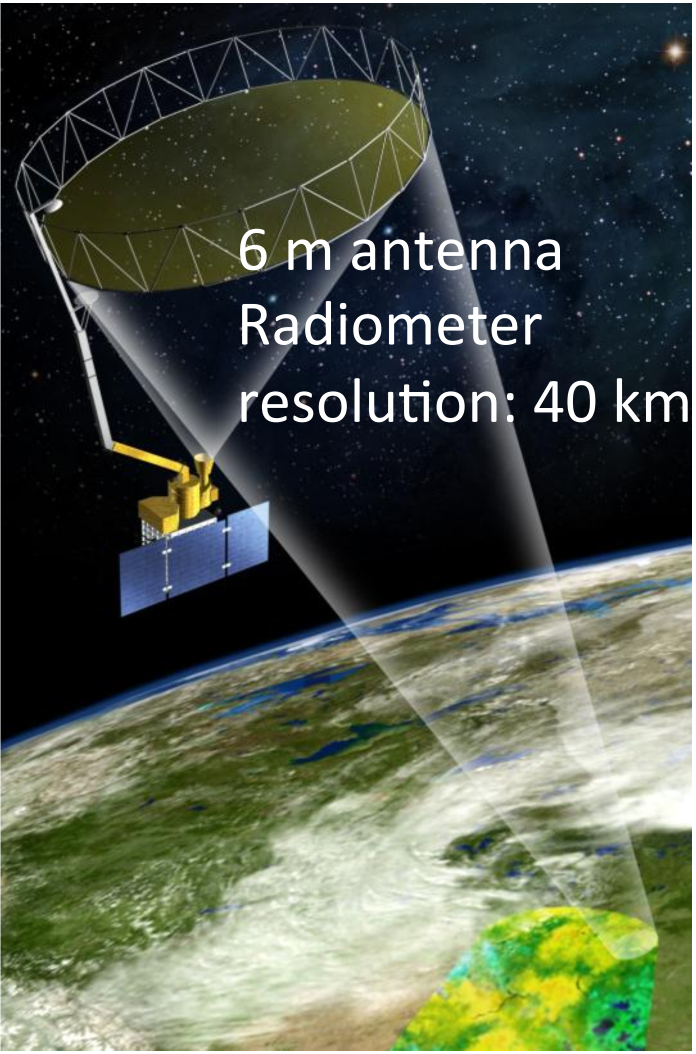
SMAP Overview



http://smap.jpl.nasa.gov/

Primary Science Objectives

- Global, high-resolution mapping of soil moisture and its freeze/thaw state to
  - Link terrestrial water, energy, and carbon-cycle processes
  - Estimate global water and energy fluxes at the land surface
  - Quantify net carbon flux in boreal landscapes
  - Extend weather and climate forecast skill
  - Develop improved flood and drought prediction capability

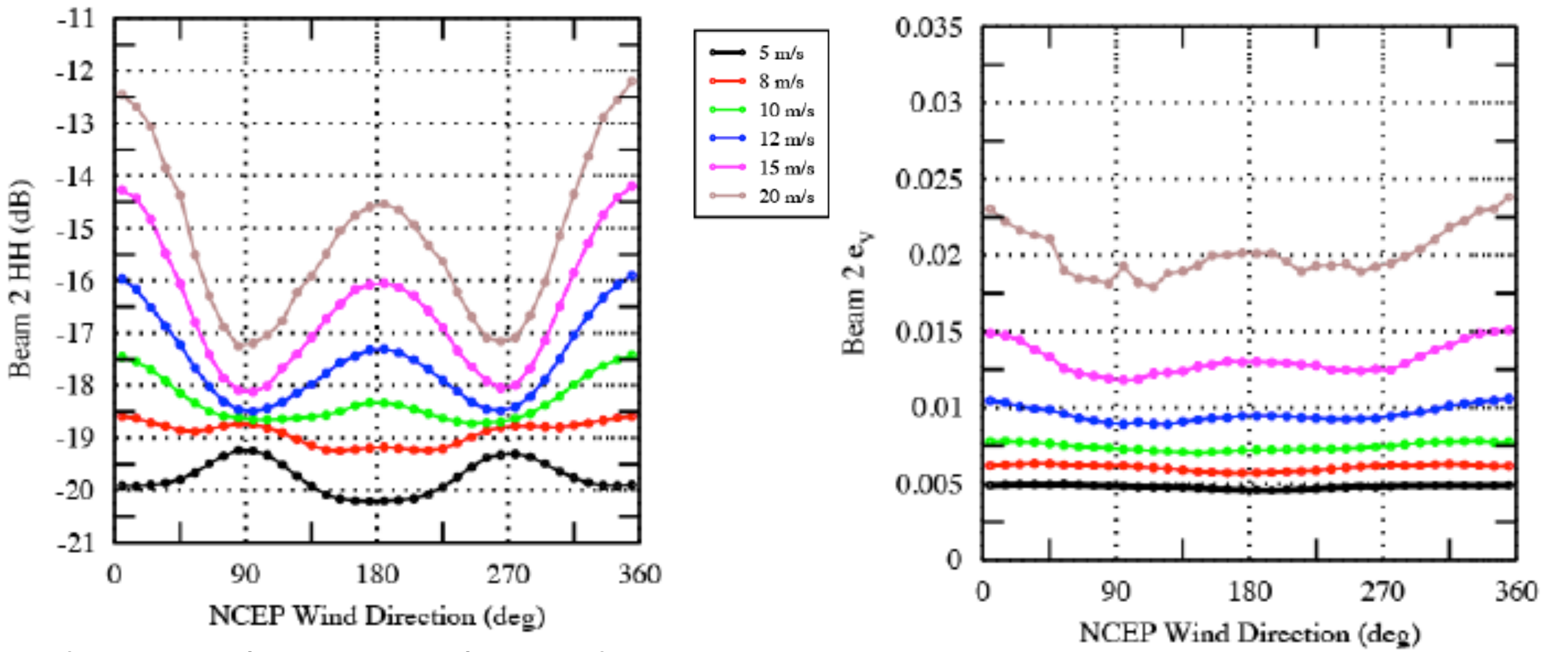
Mission Implementation

Partners	• JPL (project & payload management, science, spacecraft, radar, mission operations, science processing) • GSFC (science, radiometer, science processing)
Launch	• January 31, 2015 on Delta 7320-10C Launch System
Orbit	• Polar Sun-synchronous; 685 km altitude
Duration	• 3 years
Payload	• L-band (non-imaging) synthetic aperture radar (JPL) • L-band radiometer (GSFC) • Shared 6-m rotating (13 to 14.6 rpm) antenna (JPL)

NRC Earth Science Decadal Survey (2007) recommended SMAP as a Tier 1 mission

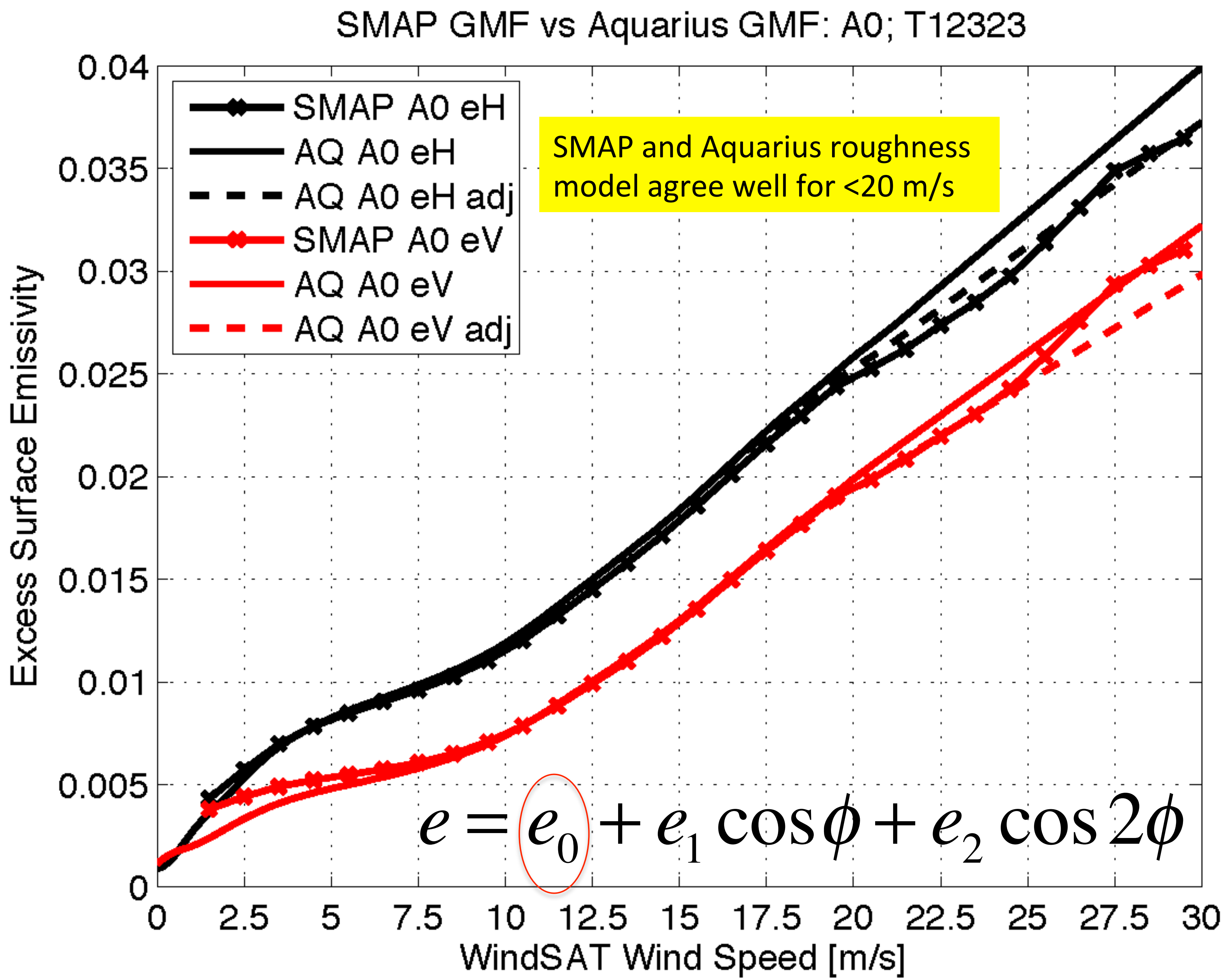
Effects of Wind/Wave on Radar and Radiometer Signals Observed by Aquarius

- The matchup of Aquarius data with NCEP wind direction, SSMIS wind speed indicates impact of ocean wind on radar and radiometer signals.
  - The charts below indicate the signal sensitivity for the data from Aquarius beam# 2 (~39 deg incidence angle)



- Radar signals vary with wind speed and wind direction
  - Cosine signal changes sign at about 8 m/s

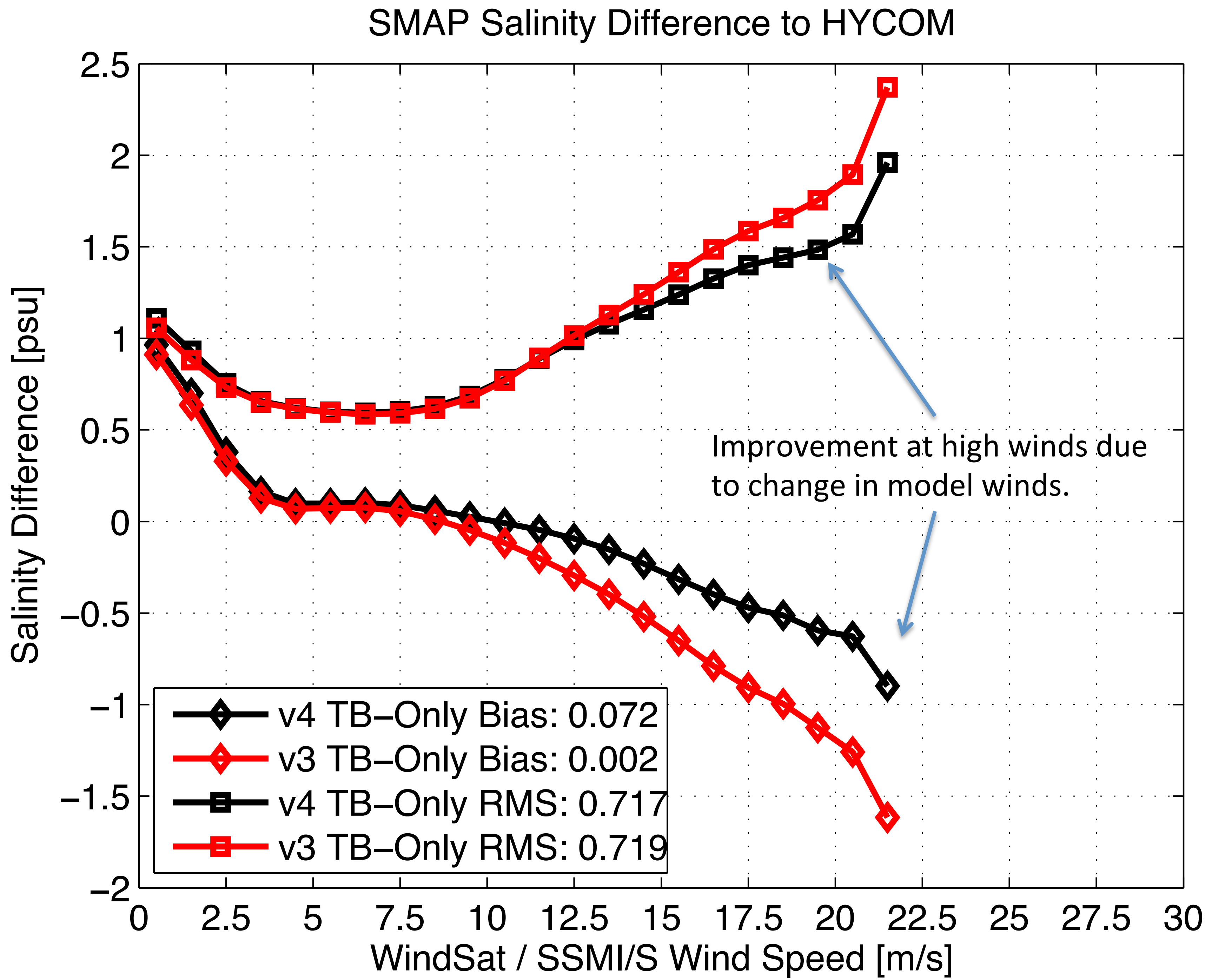
- Radio emissivity (TB/Ts) varies with wind speed and wind direction


SMAP GMF vs Aquarius GMF: A0; T12323
SMAP A0 eH
AQ A0 eH
AQ A0 eH adj
SMAP A0 eV
AQ A0 eV
AQ A0 eV adj
SMAP and Aquarius roughness model agree well for <20 m/s
$e = e_0 + e_1 \cos\phi + e_2 \cos 2\phi$
Excess Surface Emissivity
WindSAT Wind Speed [m/s]
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30

Radiometer TB SSS and Wind Processing

- Compute delta TB using ancillary data and model
  - Average over each day; use 8 day median filtered value
  - Decimated by fore/aft x asc/dec
- Grid into a 25 km L2A swath grid just like JPL scatterometer products.
  - Gridding method oversamples observations onto the grid.
  - Effective L2 resolution is somewhat larger than 40 km, closer to 50-60 km.
- Estimate wind speed and salinity using constrained objective function minimization.
- New for Version 4: Use NCEP GDAS forecasts for wind speed constraint; yields a significant improvement in high-winds.

$$F(spd, sss) = \sum_i \left[\frac{T_{B,i} - T^m_{B,i}\left(spd, sss, anc\_dir, anc\_swh, anc\_sst\right)}{NEDT_i} \right]^2 + \left(\frac{spd - spd\_anc}{1.5m/s} \right)^2,$$

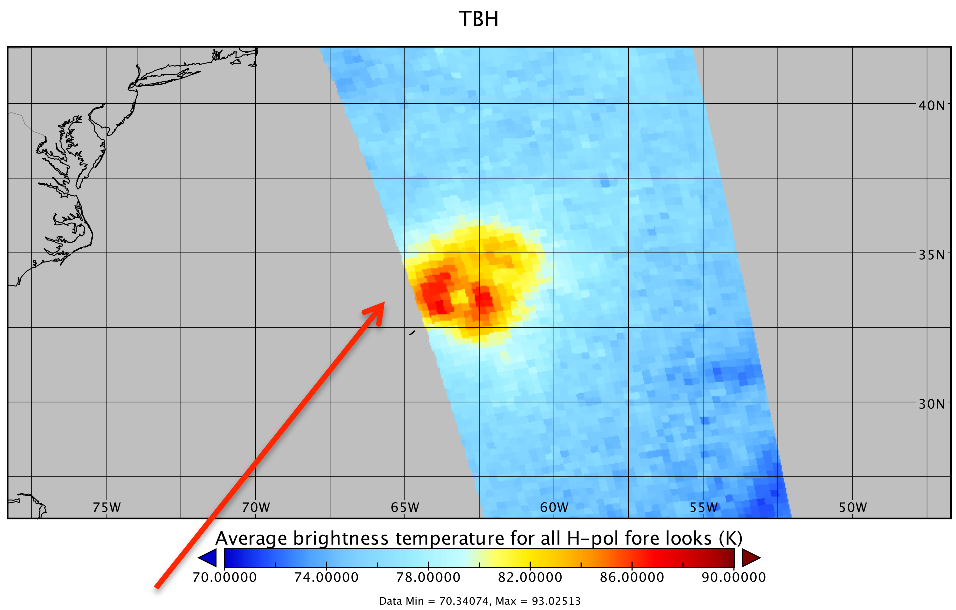


SMAP Salinity Difference to HYCOM
Salinity Difference [psu]
WindSat / SSMI/S Wind Speed [m/s]
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
Improvement at high winds due to change in model winds.
v4 TB−Only Bias: 0.072
v3 TB−Only Bias: 0.002
v4 TB−Only RMS: 0.717
v3 TB−Only RMS: 0.719

Shape of storm is better represented using forecast data instead of interpolation of 6 hour now casts.

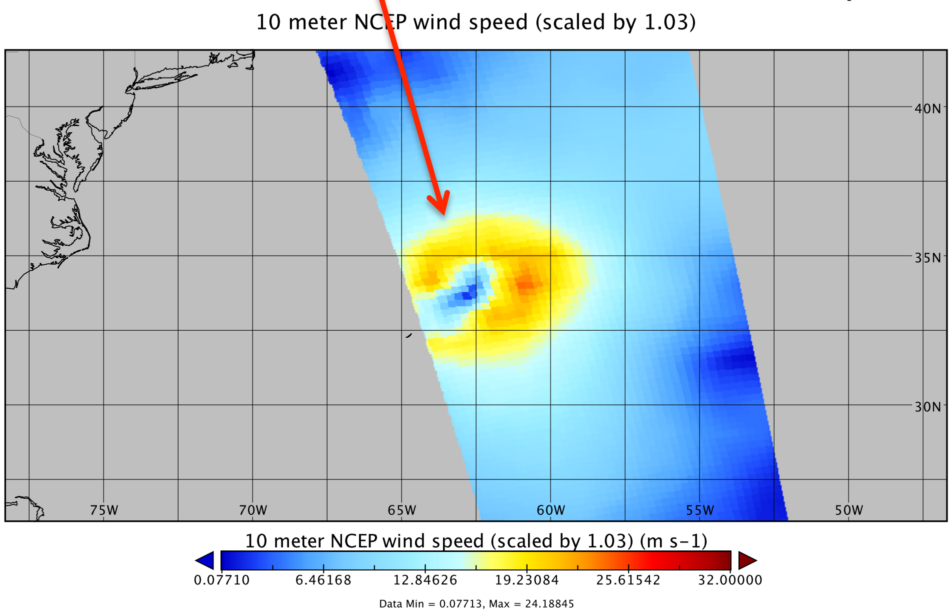
Leads to improve SSS retrievals near storms.

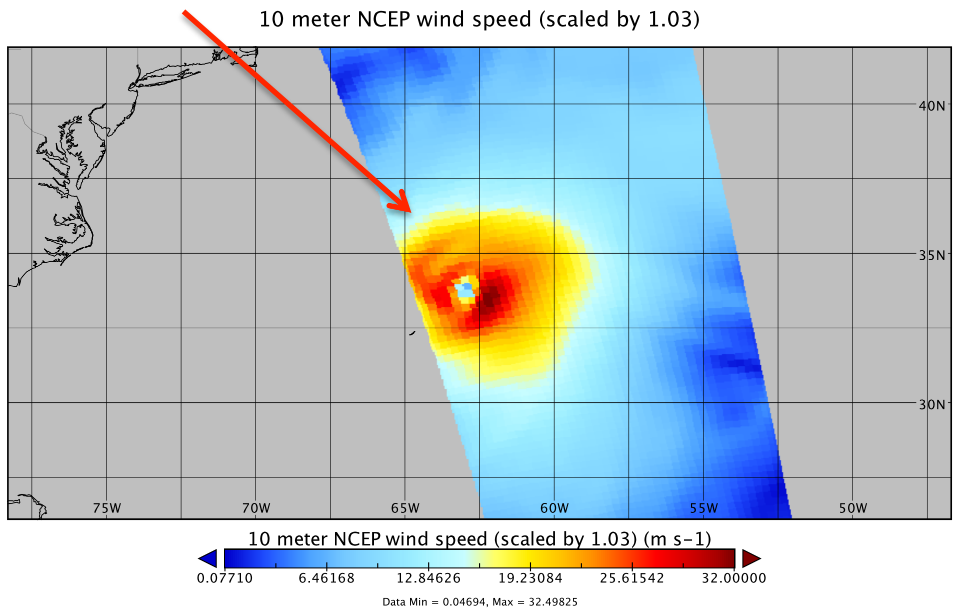
Particular improvement at high latitudes.



Smearing of eye in v3 ancillary winds.

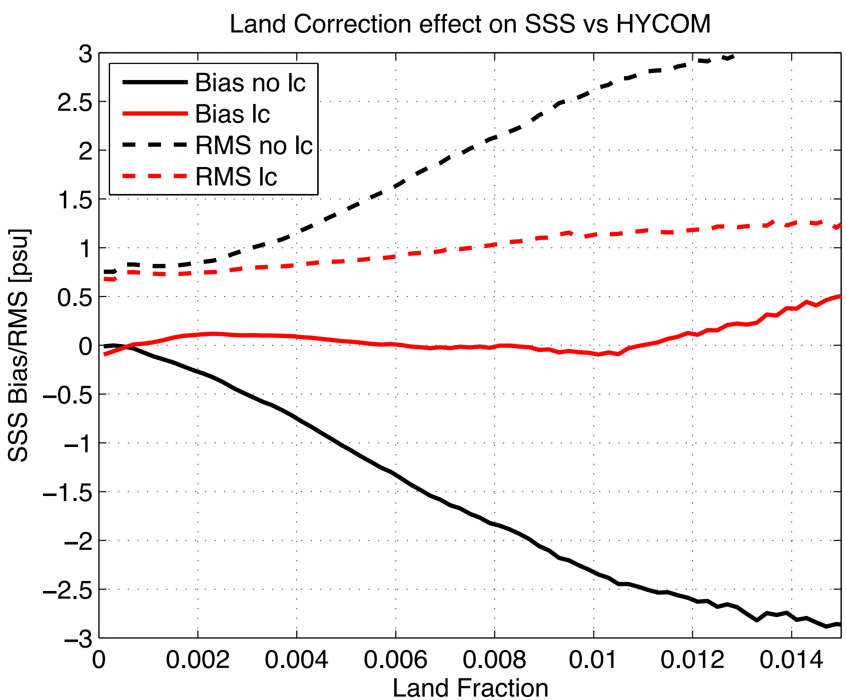
V4 ancillary winds preserve shape

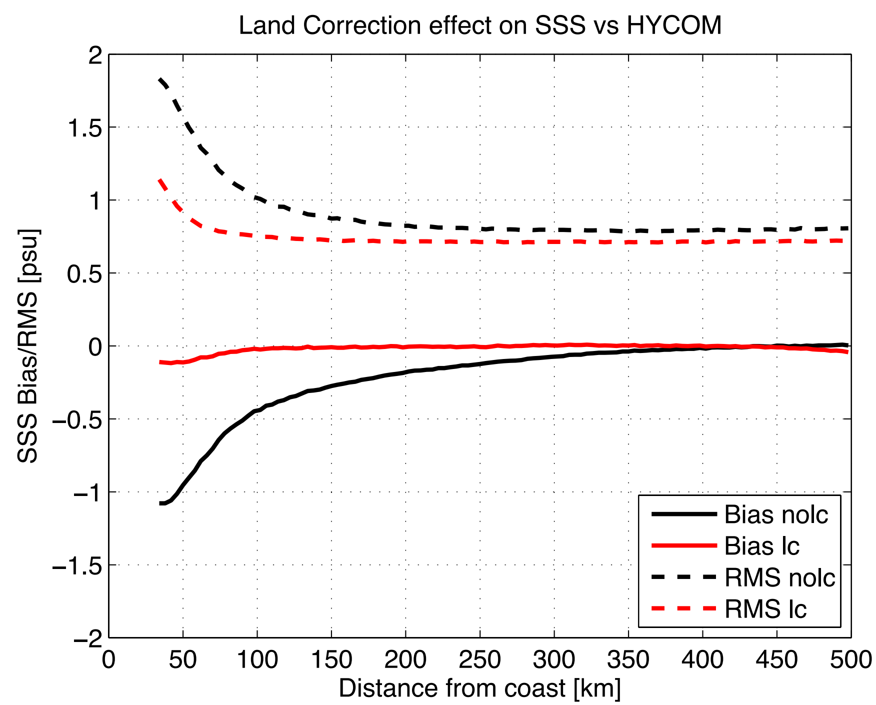




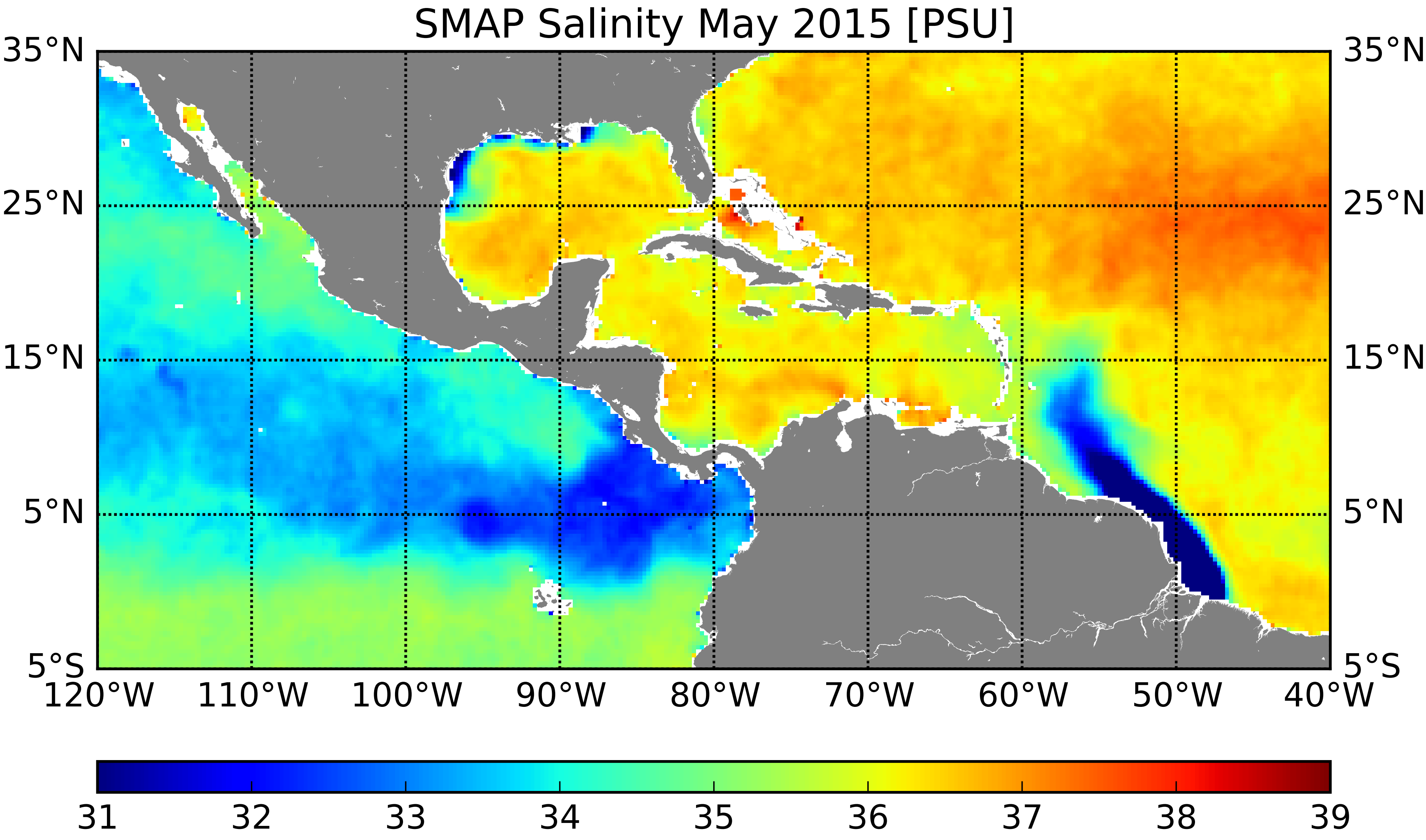
SMAP Land Correction

- Compute land fraction (f_{land}) for every T_B footprint.
  - Use look-up table to make problem feasible.
  - Look up table computed from nearly a year of beam integrated land fraction.
  - Function of lon, lat, cell azimuth angle.
- Generate a climatology of land T_B values near to footprint.
  - Represents average T_B of land not in main beam.
- Version 4 changes:
  - Retrievals allowed within 35 km from coast (v3 only > 45 km).
  - Land correction extended out to 1000 km from coast (v3 stopped at 500 km).
  - Land T_B tables updated with 2 years of data.
  - Land fraction available as L2B and L3 dataset for **user-configurable land rejection**.

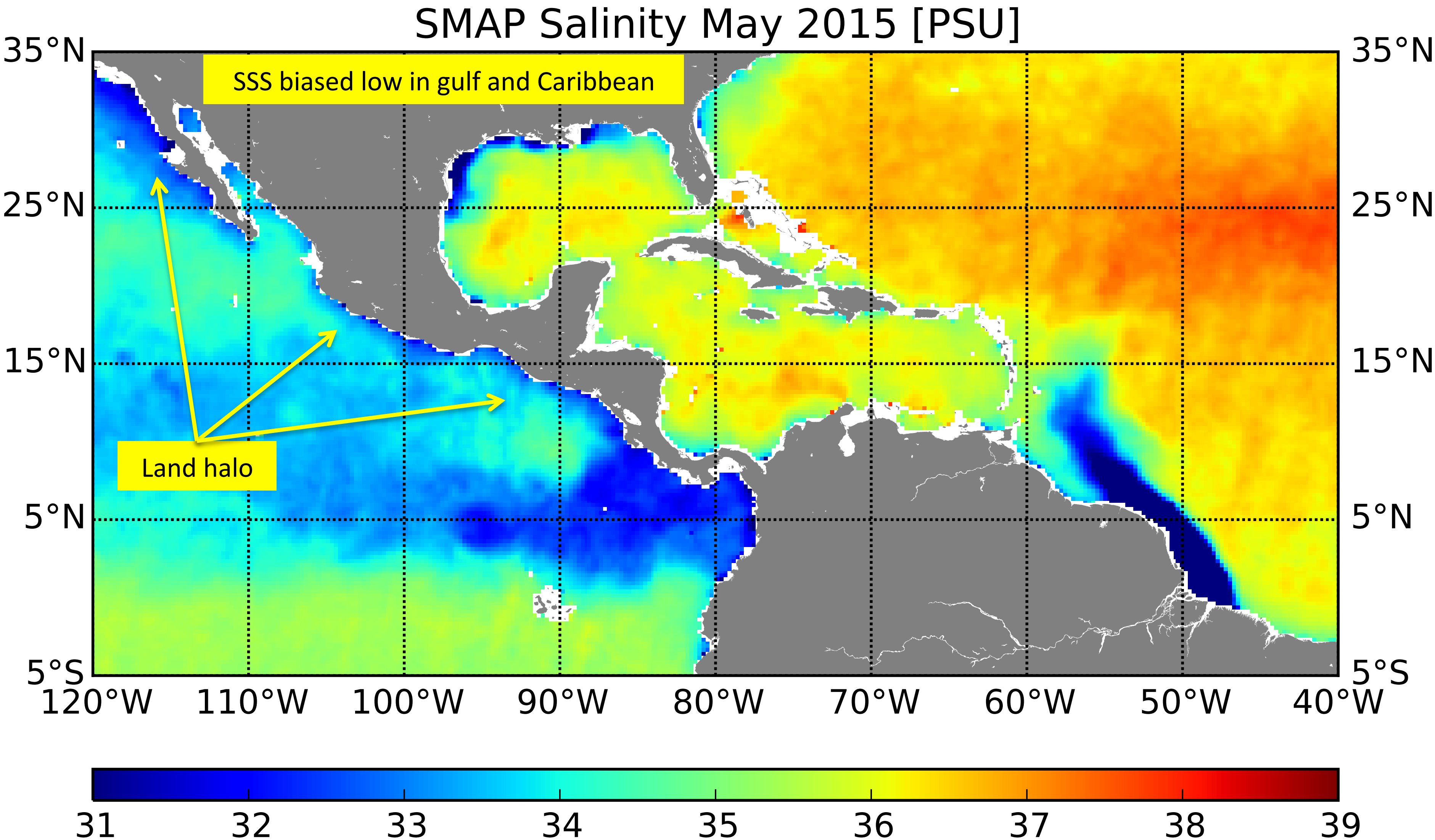




With Land Correction

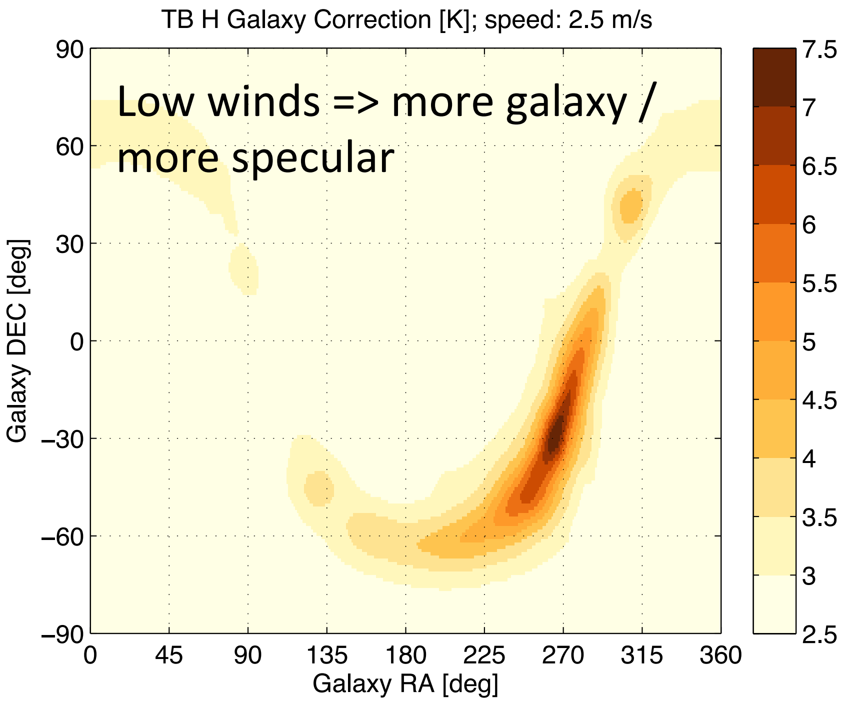


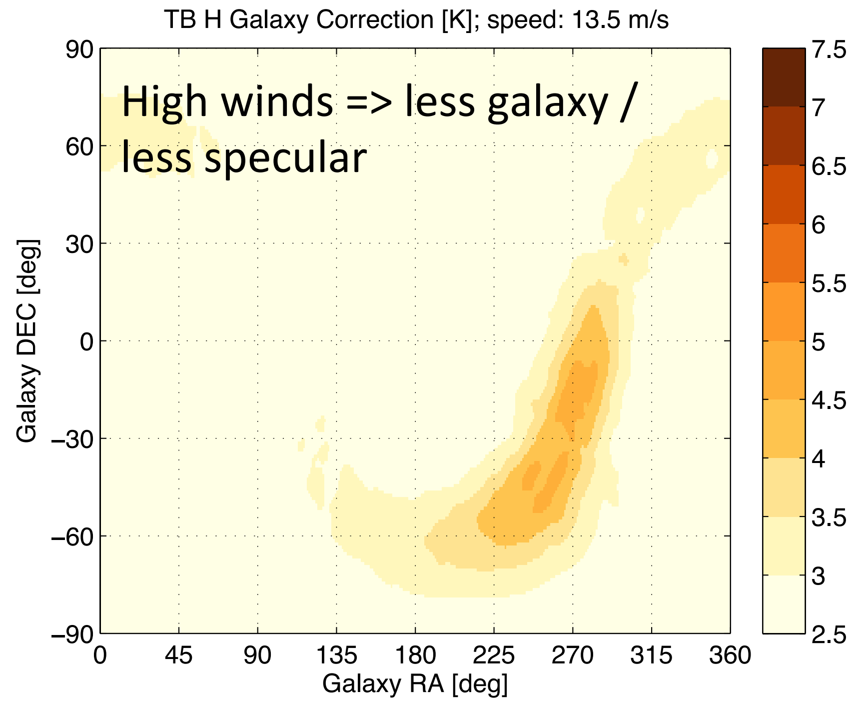
No Land Correction



SMAP Galaxy Correction

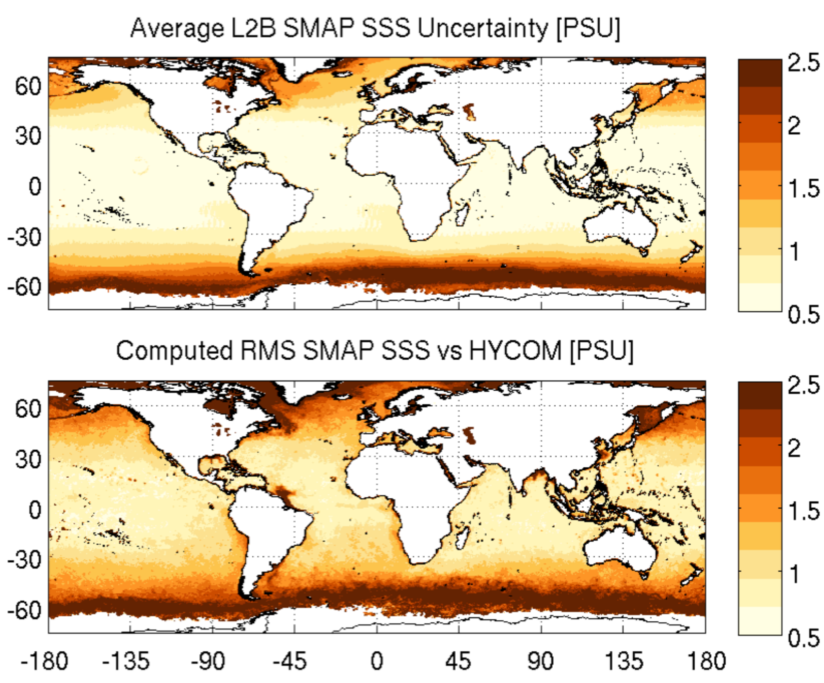
- Operational SMAP galaxy correction is not sufficient for salinity processing.
  - Operational correction is not a function of wind speed but rather a constant.
  - Direct estimation of galaxy is possible with SMAP unlike Aquarius (two look).
- With two years of SMAP; match fore look to aft look on ocean:
  - Use ancillary galaxy map to select "hot" look and "cold" look.
  - TB delta of hot-cold look nearly all due to galaxy* (after removal of sun, moon, wind direction).
  - Bin-average hot-cold delta as function of hot look galaxy RA, DEC, and surface wind speed.
- Galaxy table updated using 2 years of data for version 4.

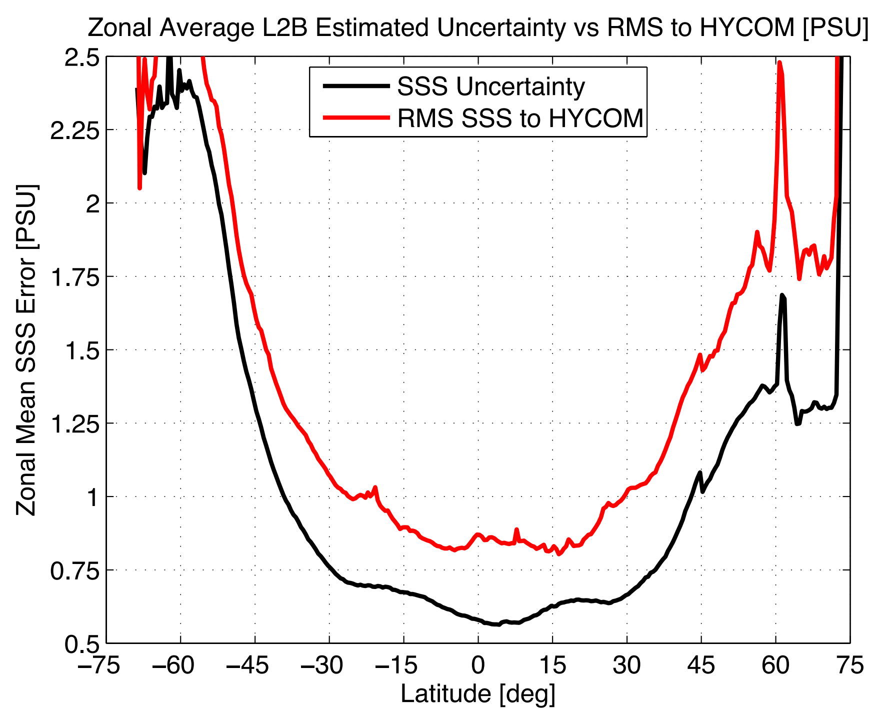




New in V4: Estimated SSS Uncertainty

- Use width of objective function minima for each SWC.
  - Captures all known information (predicted variance via NEDT).
  - Captures effects of all unknowns via residual mismatch of measurements to model function (can't model it if we don't know it).
- For L3 use propagation of variance and assumptions about correlation of adjacent SWCs and L3 binning.
- Allows for user-configurable quality control; new for version 4.0!

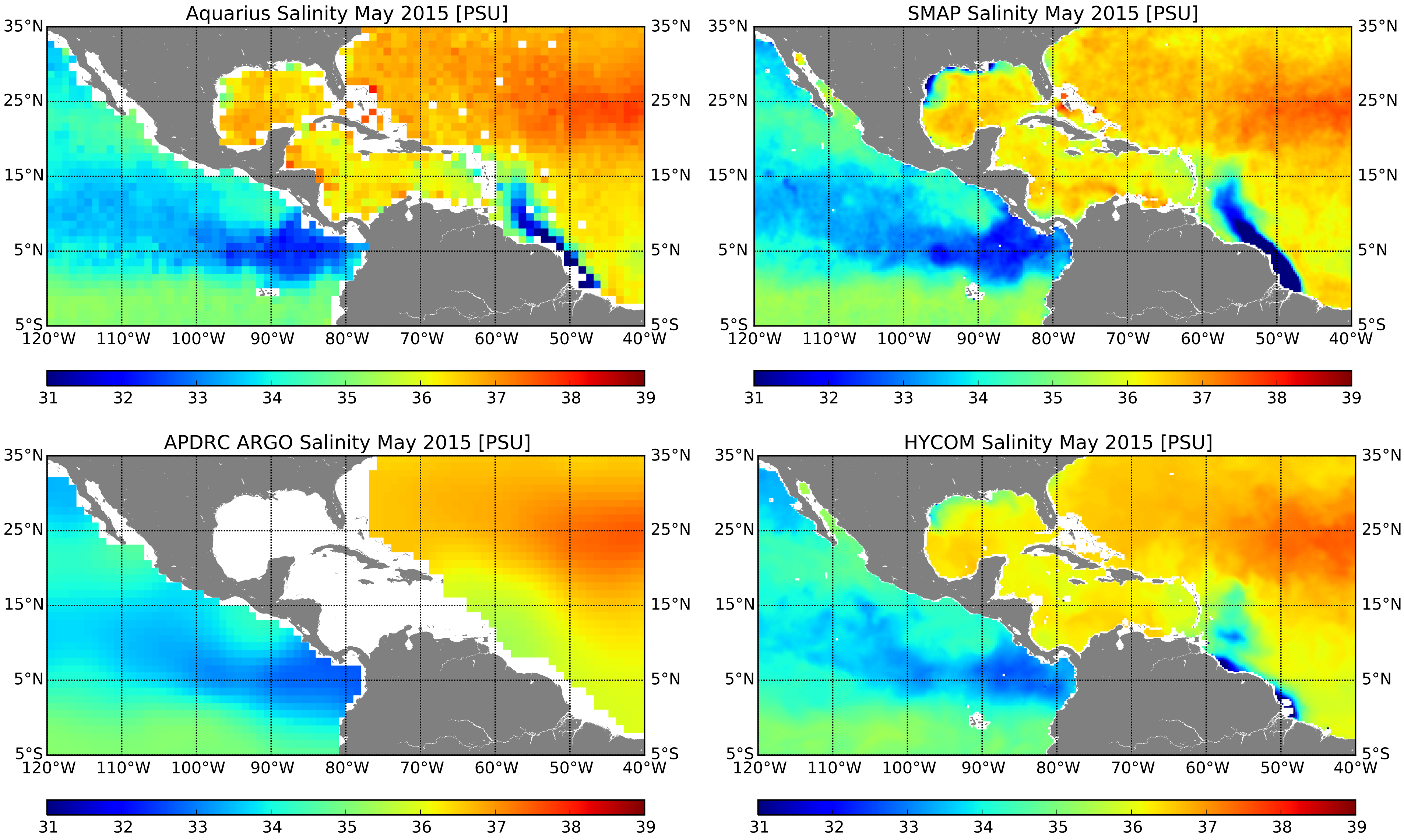




Level 3 Processing

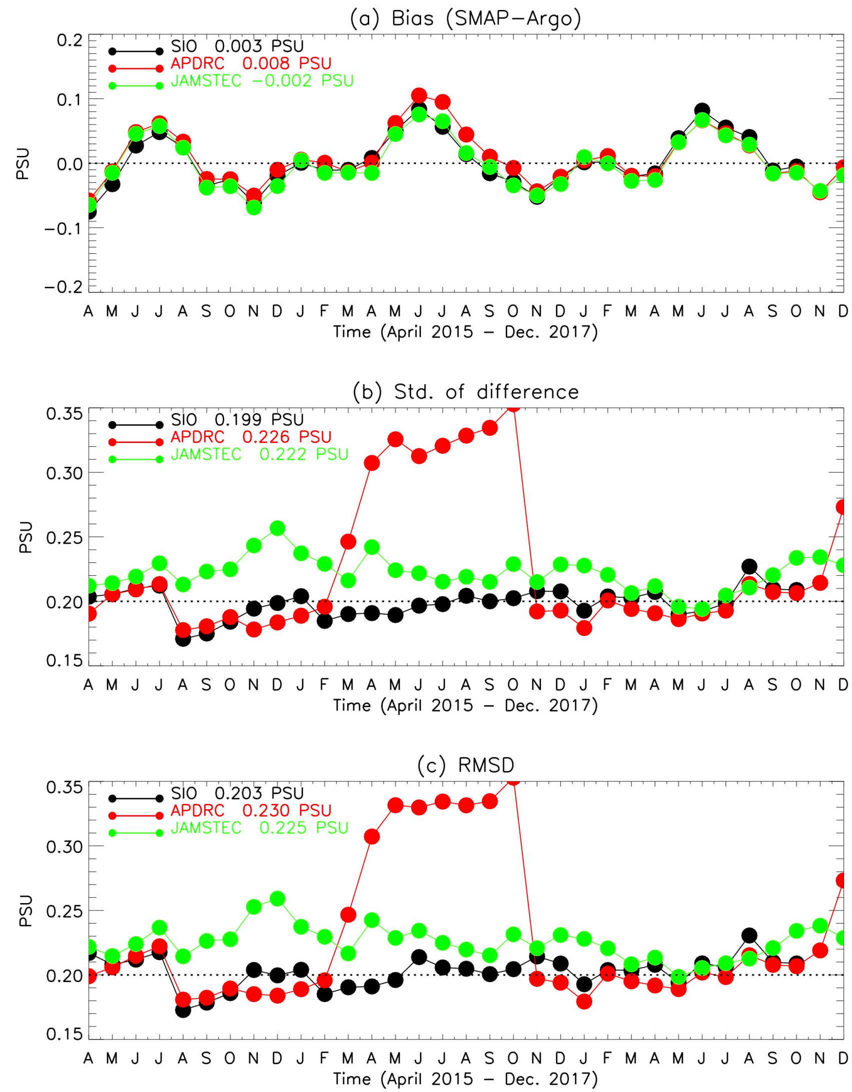
- L2B data are aggregated on a 0.25 x 0.25 geographic grid.
- Two flavors of L3 data:
  - Moving 8-day time average centered on 1200 UTC +/- 4 days.
  - Monthly time average: all orbits that start in that month.
- Use Gaussian weighting to aggregate L2B swath data onto fixed grid:
  - Half-power radius of 30 km
  - Cut-off radius of 45 km
- SMAP L3 resolution slightly larger than 60 km; Aquarius was ~ 100-150 km.

Sea Surface Salinity Maps May 2015



SMAP L3 versus ARGO

- Bias/STD/RMS of 1x1 deg averaged monthly SMAP V4:
  - ARGO SIO (black)
  - ARGO ADPRC (red)
  - JAMSTEC (green)
- *JPL SMAP has monthly STD of just under 0.2 PSU – meeting Aquarius science requirements.*



Summary of SMAP and SMOS vs. Buoy

- Excellent agreement between SMAP and mooring SSS in the tropical oceans based on the summary of statistical differences between them for 29 buoys with contiguous time series of SSS during April 2015 and August 2016.
- OI: 45 km search radius and 30 km half power

SMAP	Bias	Standard Deviation	Correlation
15 day average	0.07 psu	0.22 psu	0.73
30 day average	0.05 psu	0.17 psu	0.80

SMOS	Bias	Standard Deviation	Correlation
15 day average	-0.15 psu	0.26 psu	0.63
30 day average	-0.16 psu	0.22 psu	0.71

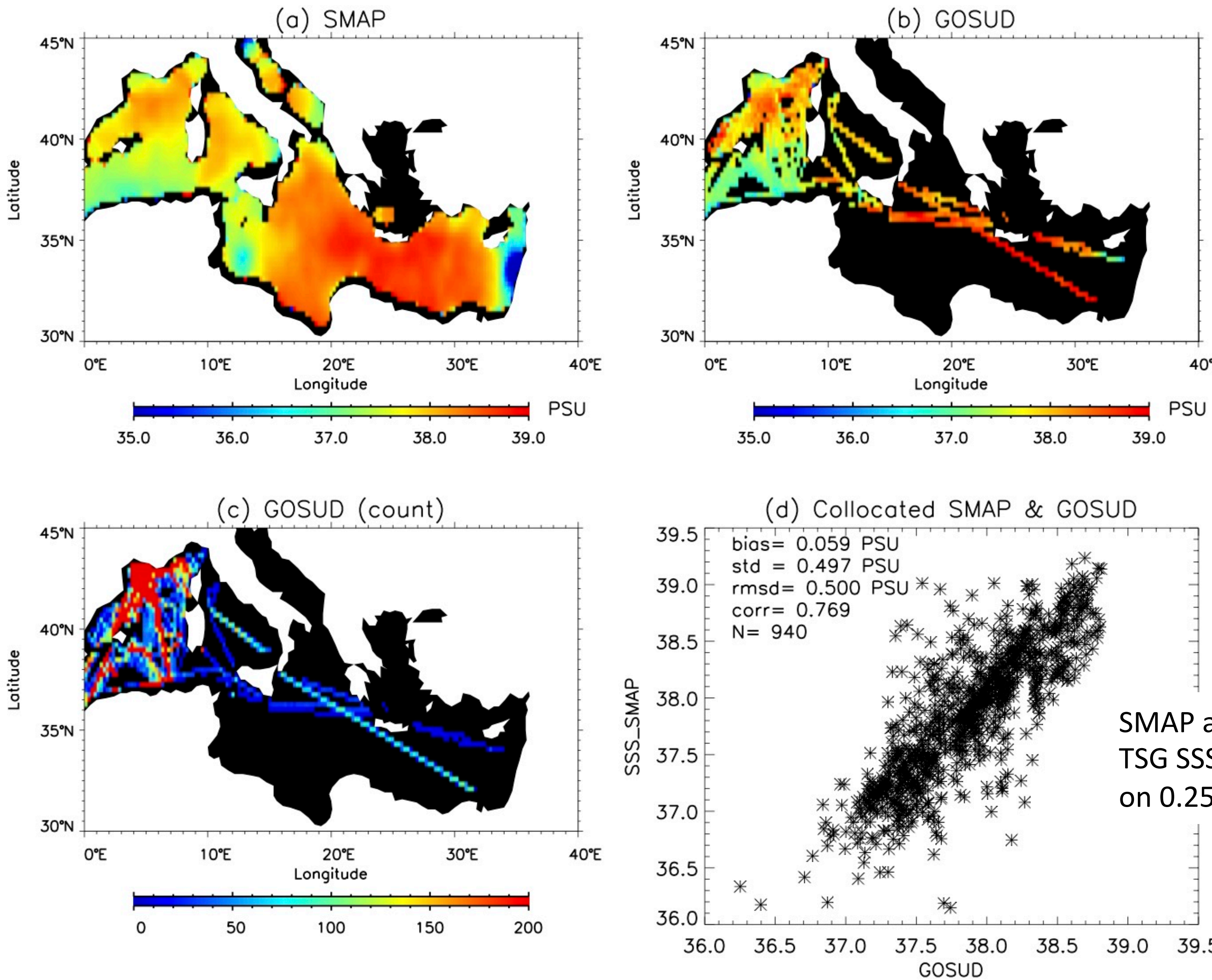
Summary

- SMAP radiometer-only data is capable of providing a ocean salinity data product that meets the Aquarius science requirement of 0.2 PSU:
  - 0.2 PSU STD as compared to SIO ARGO at 1x1 deg monthly scale.
  - 0.17 PSU STD as compared to tropical moored buoys at 1x1 deg monthly scale.
- Version 4 improves on previous algorithm:
  - Improved coastal correction + SSS in very large lakes.
  - Extended range of SSS retrievals to 45 PSU.
  - Improved roughness correction using forecast data.
  - Addition of **land fraction** and **SSS estimated uncertainty** at L2 and L3 for **user-configurable data rejection**.
- Data are available at http://podaac.jpl.nasa.gov
  - L2B with a 3 day delay.
  - L3 with a 7 day delay from center of 8-day window.
- NRT data available at ftp://sealion.jpl.nasa.gov/outgoing/smap
  - L2B NRT data have about 4.5 hour median latency.

Publications

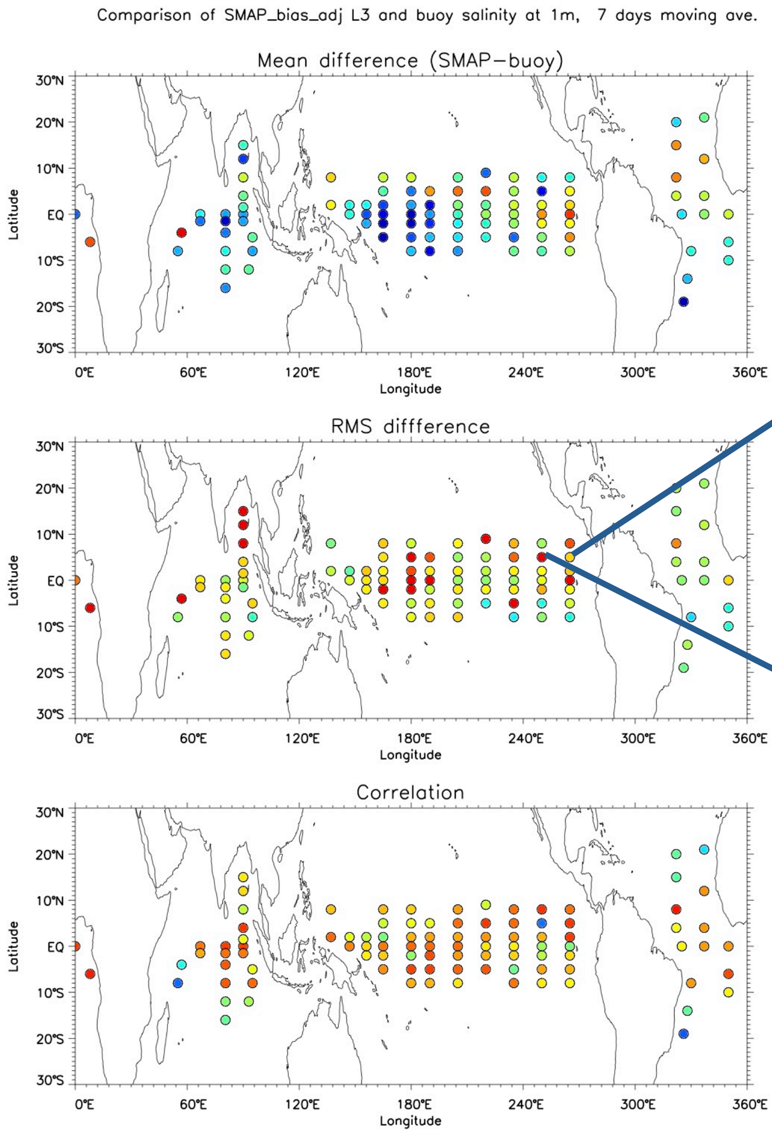
- Publications
  - Fore, A., S. Yueh, W. Tang, B. Stiles, and A. Hayashi (2016). Combined Active/Passive Retrievals of Ocean Vector Wind and Sea Surface Salinity with SMAP, IEEE Trans. Geoscience and Remote Sensing, doi: 10.1109/TGRS.2016.2601486.
  - Yueh, S., A. Fore, W. Tang, H. Akiko, B. Stiles, N. Reul, Y. Weng and F. Zhang, (2016): SMAP L-band passive microwave observations of ocean surface wind during severe storms, *IEEE Trans Geosci. Remote Sens.*, doi:10.1109/TGRS.2016.2600239.
  - Wenqing Tang, Alexander Fore, Simon Yueh, Tong Lee, Akiko Hayashi, Alejandra Sanchez-Franks, Brian King, Dariusz Baranowski, and Justino Martinez (2017): “Validating SMAP SSS with in situ measurements,” Remote Sensing of Environment, doi:10.1016/j.rse.2017.08.021

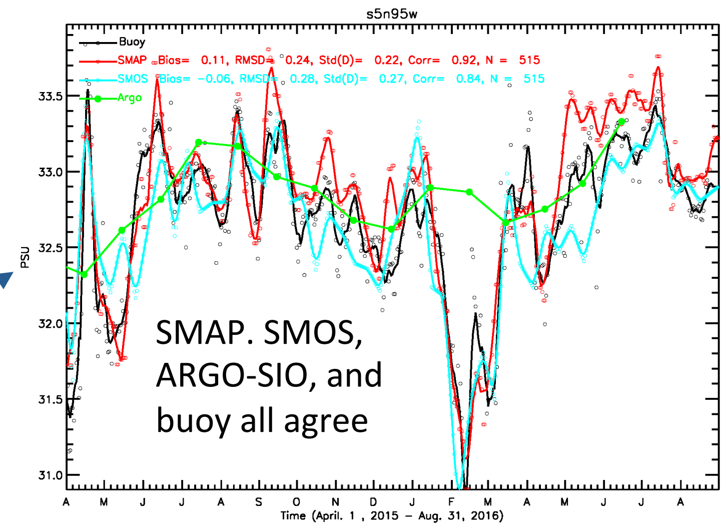
JPL SMAP SSS and GOSUD Ship TSG Comparison in the Mediterranean (2015-2016)

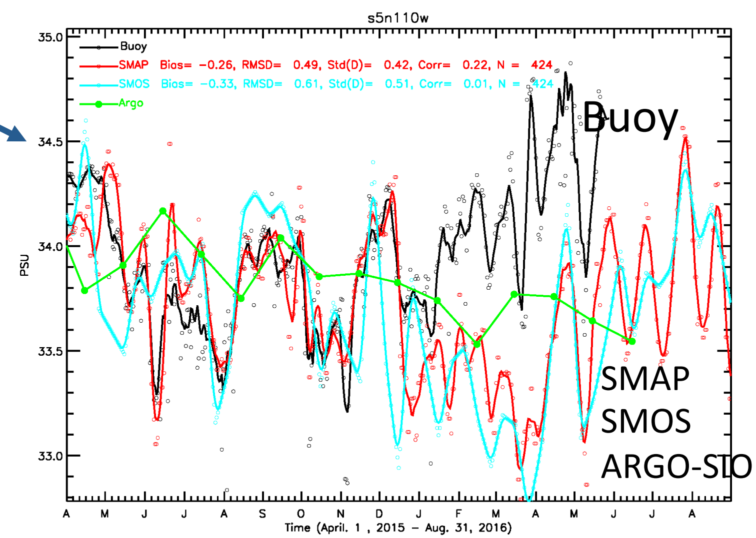


SMAP and GOSUD ship TSG SSS data are binned on 0.25 deg grid

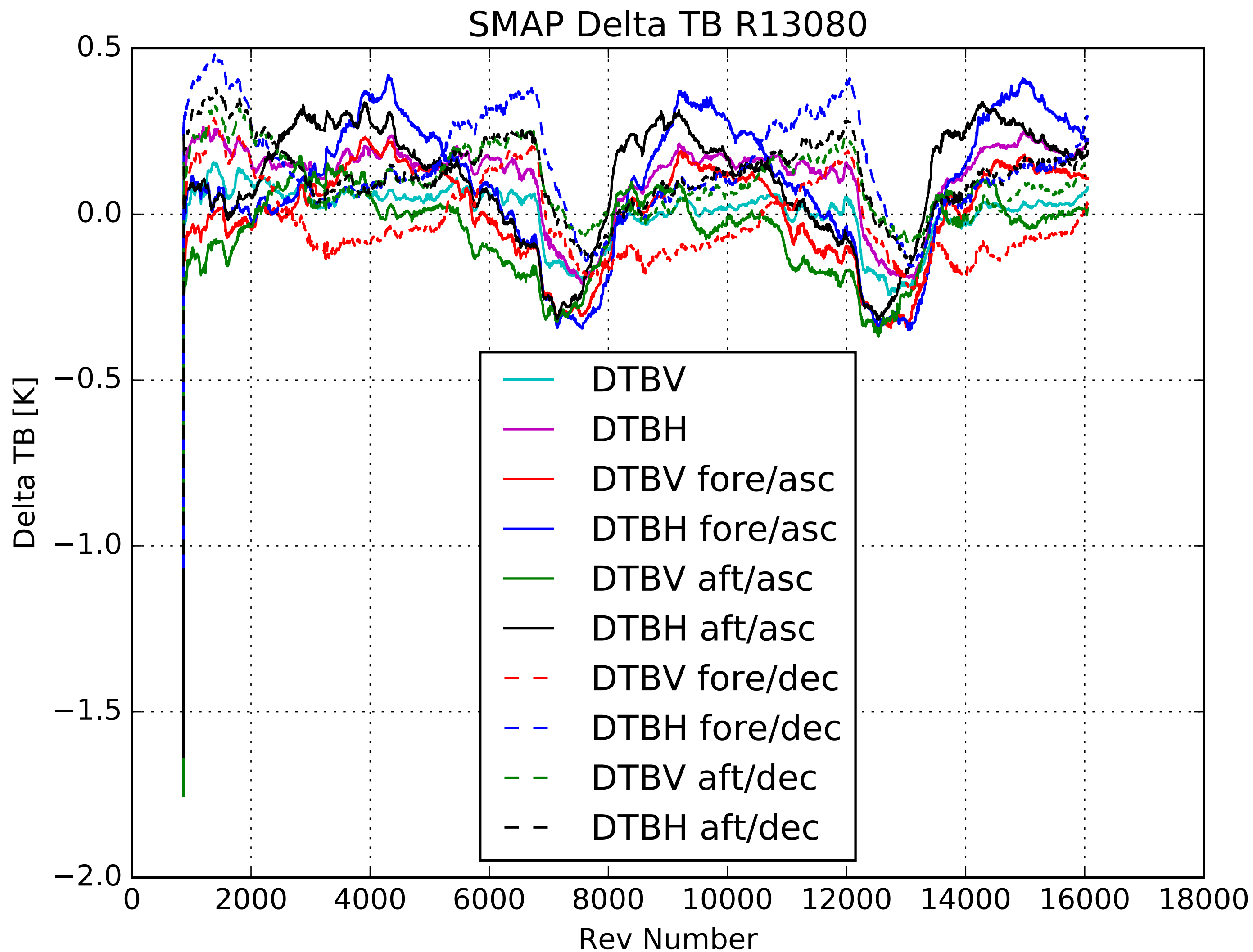
SMAP Salinity Comparison with Buoys



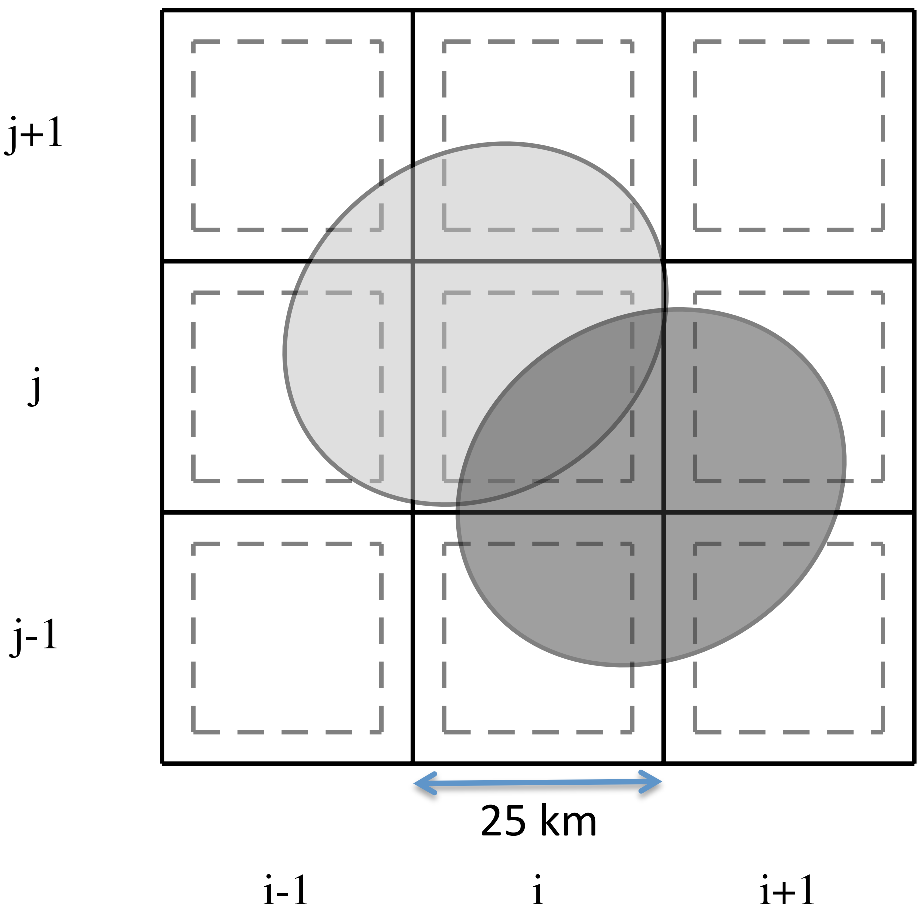


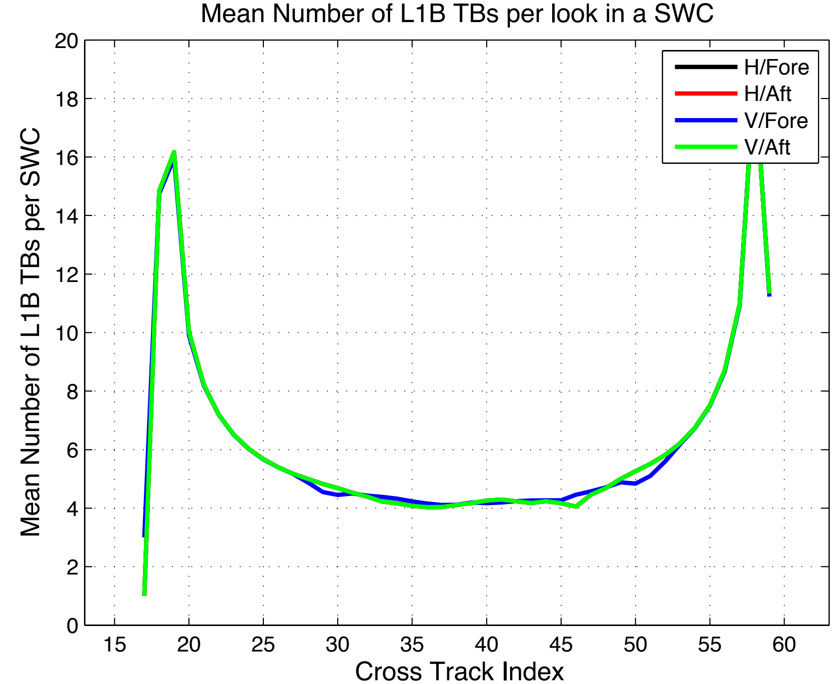


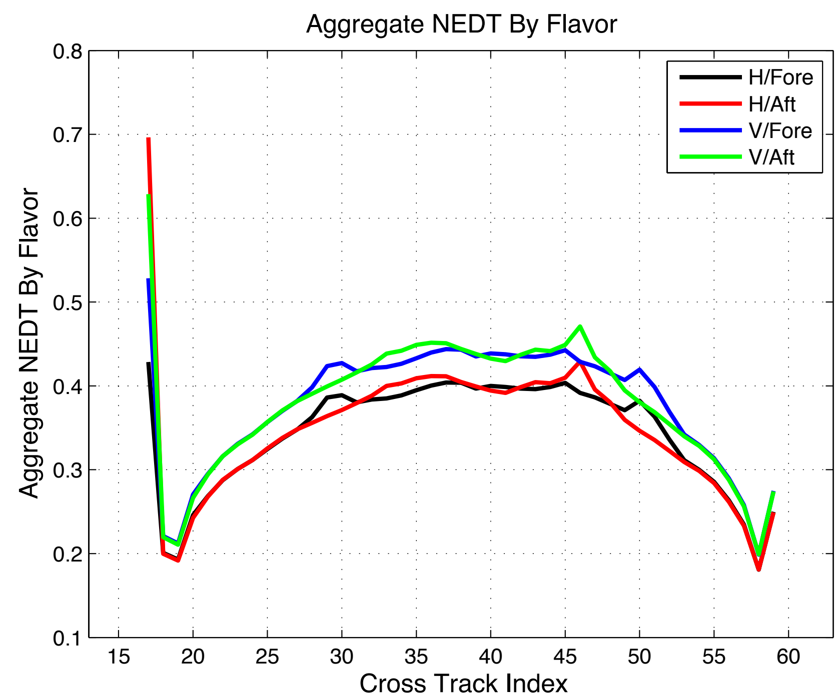
Comparison charts requested by and sent to PMEL


SMAP Delta TB R13080
Delta TB [K]
Rev Number
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
DTBV
DTBH
DTBV fore/asc
DTBH fore/asc
DTBV aft/asc
DTBH aft/asc
DTBV fore/dec
DTBH fore/dec
DTBV aft/dec
DTBH aft/dec

L2A Gridding

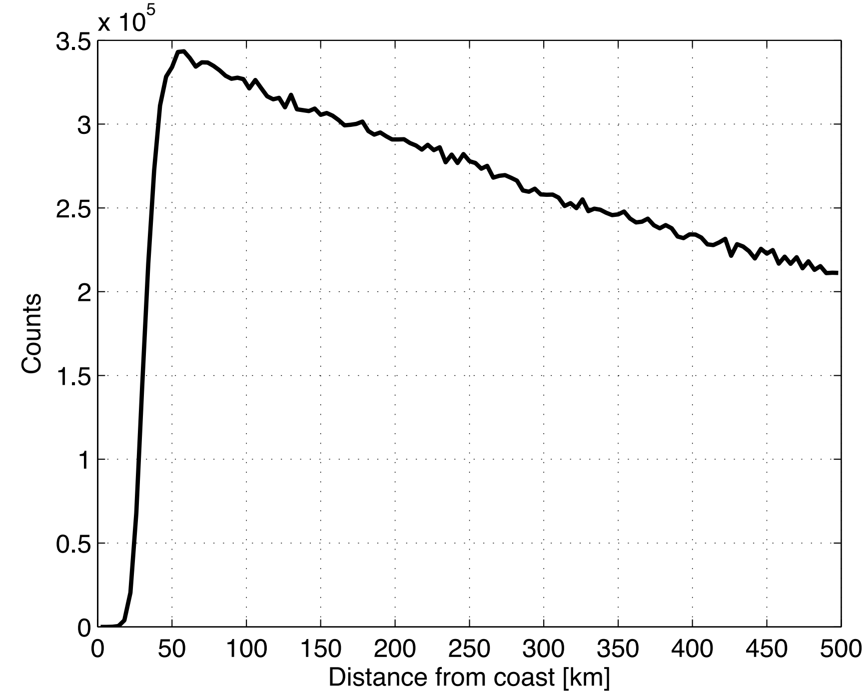


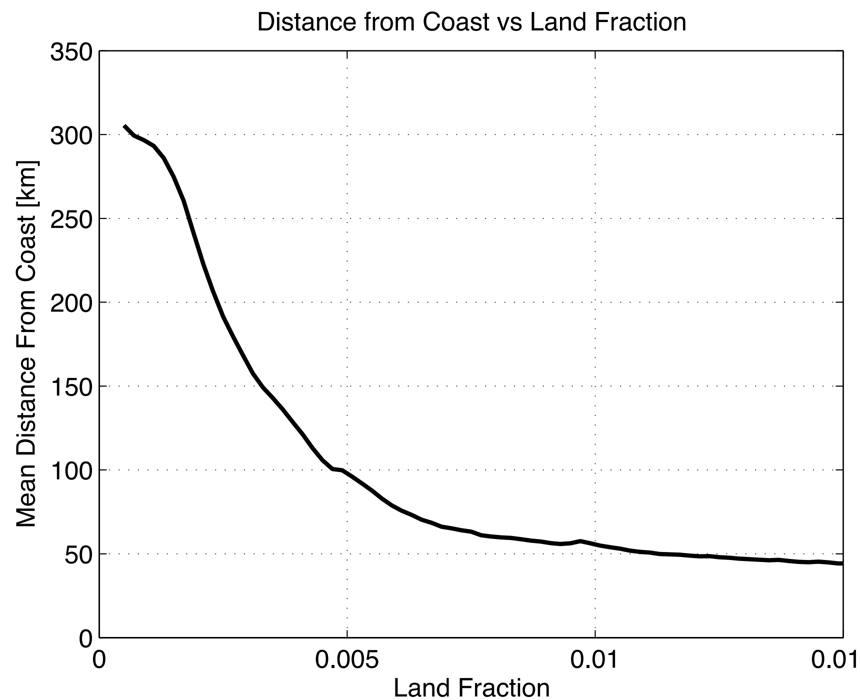


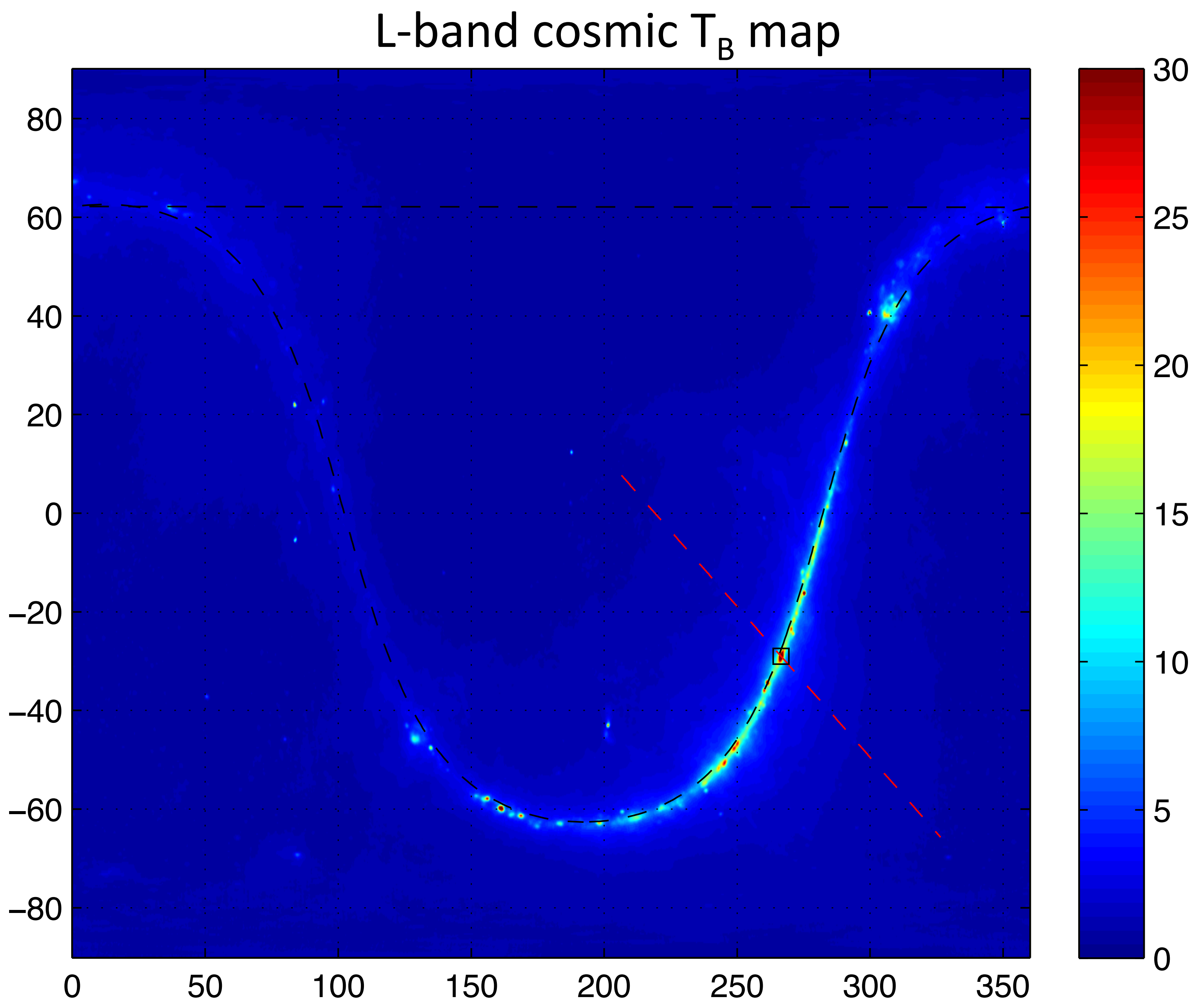


Land Correction Backup Figs

$$T_{corr} = \left(T_B - f_{land} T_{B,land}\right) / \left(1 - f_{land}\right)$$







L-band cosmic T_B map
80
60
40
20
0
−20
−40
−60
−80
0
50
100
150
200
250
300
350
30
25
20
15
10
5
0